Jurnal Teknologi

Full paper

Properties of Asphaltic Concrete Containing Sasobit®

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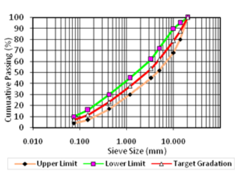
Article history

Received :5 June 2014
Received in revised form :
25 September 2014
Accepted : 16 October 2014

Graphical abstract



Abstract

With increasing interest in the use of hot mix asphalt in the paving industry, more studies in this field for improvement of hot mix asphalt properties seem to be necessary. Hence, the main objective of this study was to investigate the effect of sasobit® content as modified binder in hot mix asphalt. 60/70 penetration grade asphalt was separately modified with sasobit® at different concentrations ranging from 0% to 4.5%. The influence of sasobit® on the hot mix asphalt mixtures properties were detected through conventional tests i.e. penetration and softening point. In addition, the Marshall stability, abrasion loss, and resilient modulus were also examined. Results indicated that the hot mix asphalt containing Sasobit® additive has significant affect in terms of penetration and softening point. Furthermore, the addition of Sasobit® seemed to improve the stability, abrasion loss and modulus of stiffness.

Keywords: Road transportation; greenhouse gas; emission reduction; mitigation; climate change

1.0 INTRODUCTION

Road has played an important role in the trade and transportation system throughout the world, and it became rapid increase in the pavement infrastructure development in Malaysia [1, 2]. In Malaysia, 95% of the roads uses asphaltic concrete (flexible pavement) and the rest consist of concrete pavement or concrete block pavement [3]. Flexible pavement, usually asphalt concrete, is laid with no reinforcement or with specialized fabric of reinforcement that permits limited flow or repositioning of the roadbed underground changes. The design of flexible pavement is based on the characteristic of the load distribution of the component layers [4, 5]. Each pavement layer has a multitude of functions which has to be considered during the design process depending upon the traffic requirements [6]. Improper design can lead to early pavement failure which can affect the riding quality [7]. In order to minimize the deterioration and increase the service life of the designed road, the bituminous layers should be improved with regard to performance properties, such as resistance to permanent deformation, fatigue, wear, and stripping, aging and etc. [8, 9]. Recently, the substitution of industrial material as a modifier to modify asphalt properties has been taken into consideration, in order to reduce life cycle costs and obtain environmental benefits. In this study, the effect of adding Sasobit® in bitumen to improve the performance of asphaltic concrete was investigated. The use of Sasobit® in asphalt pavement can be seen as a solution to the pavement deterioration problems [10]. Sasobit® which is organic additives is use to reduce the viscosity of the binder at mixing and compaction temperatures. Sasobit is a fine crystalline, long chain aliphatic hydrocarbon produced from coal gasification using Fischer Tropsch (FT) process and is known as FT paraffin wax [11, 12]. Sasobit® shows the appearance of flake or powder, and its melting point is greater than 100°C [5, 10]. According to previous research [13], when Sasobit® is added to asphalt at a temperature below its melting point which is greater than 100 Celsius, Sasobit® forms a lattice structure in asphalt and improves the asphalt's viscosity. However, when Sasobit® is blend into the asphalt at temperature higher than its melting point, Sasobit® completely dissolves in asphalt and reduces the asphalt viscosity. Thus, it can decrease the working temperature of asphalt and reduce mixture in 30°C to 50°C. By now, it can be accepted that Sasobit® not only reduces the working temperature of asphalt mixture but also ensures the performance of asphalt mixture, which is equivalent with the hot mix asphalt.

2.0 MATERIALS AND EXPERIMENTAL PROCEDURES

2.1 Binder and Aggregate

The binder used in this study was a conventional penetration grade 60/70 and Sasobit® modified binder supplied by Shell Malaysia. The conventional binder was a typical grade used on Malaysian roads [14]. There are a number of tests to assess the properties of bituminous materials. In this study, the bitumen tests used to evaluate the influence of modified Sasobit® were penetration and softening point test. On the other hand, granite aggregates supplied by Kim Seng Quarry Sdn. Bhd. were used throughout this investigation. To arrive at a final blend in mixture proportioning, the aggregates were washed, dried and sieved into their respective size range [15].

2.2 Gradation

Sieve analysis was done to isolate aggregates from the stockpiles and combined to the aggregate gradation that meets the JKR specifications for AC14 (JKR/SPJ/2008) as shown in Figure 1.

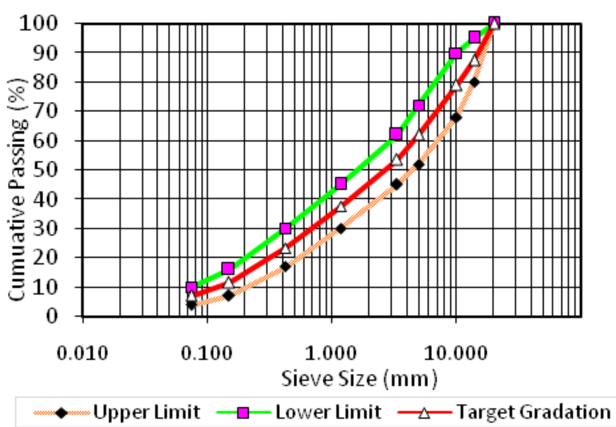


Figure 1 AC14 gradation used in this investigation

2.3 Preparation of specimen

A typical 101.6 mm inner diameter steel Marshall Moulds were used in conjunction with the Marshall hammer. Both Marshall and collar moulds and base plates together with the aggregates were placed in an oven set at the desired mixing temperature for a period of at least 4 hours. The bitumen was placed in the oven at the required mixing temperature until it was fully liquefied for mixing with the aggregates. An electrically heated paddle mixer was used to blend the aggregates and bitumen. Mixing of dry aggregates was accomplished in less than 30 seconds and the wet mixing continued for further 1 minute. Full compaction was then carried out using the Marshall hammer with 75 blows per face. In this investigation, the effects of Sasobit® modified bitumen on the asphaltic concrete properties were studied by conducting Marshall Stability, abrasion loss, and resilient modulus test.

2.4 Penetration Test

This method was conducted to examine the consistency of a sample of asphalt by determining the distance in tenths of a millimeter that a standard needle penetrates vertically into a sample of the material used fixed conditions of temperature, load and time. The penetration test was conducted with 100 gram loads for 5 seconds at temperature of 25°C.

2.5 Softening Point Test

In order to determine the softening point of asphalt within range 30°C to 157°C by means of the Ring-and-Ball apparatus. Asphaltenes materials do not have a definite melting point. Instead, as the temperature rises, these materials slowly change from brittle or very thick and slow flowing materials to softer and less viscous liquids. A steel ball of specified weight is placed upon a disk of sample contained within a horizontal, shouldered, metal ring of specified dimensions. The softening point taken as the temperature at which the bitumen becomes soft enough to allow the ball enveloped in the asphaltenes material to fall a distance of 25.4 mm. for an asphalt of a given penetration (determined at 25°C), the higher the softening point the lower the temperature sensitivity.

2.6 Abrasion Loss Test

According to ASTM C131-01, a Marshall sample was subjected to 100, 200, and 300 drum rotations in the Loss Angeles drum at ambient temperature of 29°C. The abrasion loss was expressed in term of the percentage mass loss compared to the original mass as illustrated in Equation 1. The test method adopted followed the procedure [16]. Specimens were tested at Sasobit® content ranging from 0% to 4.5%.

$$P = \frac{P1-P2}{P1} \times 100 \qquad \text{Equation (1)}$$

2.7 Resilient Modulus Test

A five pulse indirect tensile modulus test conforming to ASTM [17] test method was conducted using the Universal Testing Machine, MATTA. The specimen was tested at 25°C after a 4-hour-conditioning period. In the test, a pulsed diametral loading force was applied to a specimen and the resulting total recoverable diametral strain was then measured. For controlled temperature testing, the specimen's skin and core temperatures were estimated by transducers inserted in a dummy specimen and located near the specimen under test. The test procedure was repeated by orientating the specimen at 90 degree.

3.0 RESULTS AND DISCUSSION

3.1 Penetration

The penetration value decreases as the content of Sasobit® increases as illustrated in Figure 2. The results also show that the bitumen becomes more viscous and harder, which would be useful to obtain stiffer asphaltic concrete [18]. This is an indication of an enhanced resistance against permanent deformation of the asphaltic concrete using Sasobit® modified bitumen during the service life of pavement.

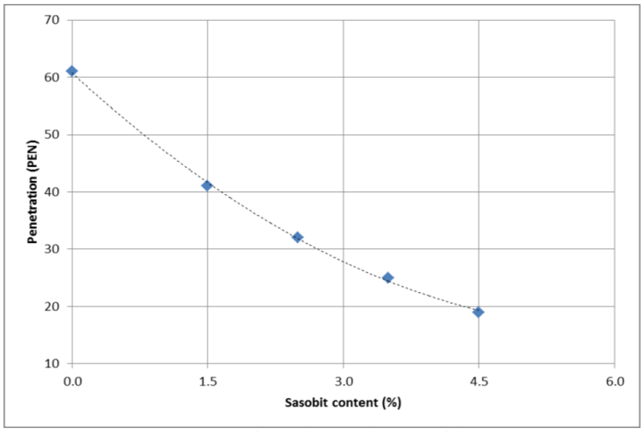


Figure 2 Penetration value against Sasobit® content

3.2 Softening Point

The softening point of specimens was meets the JKR specification which requires the softening point between 40 ºC to 100ºC as presented in Figure 3. As the Sasobit® content increases, the softening point of specimens also increases. It can be said that modified bitumen become less susceptible to temperature changes as the content of Sasobit® increases. Generally, temperature in Malaysia is around 23ºC to 33ºC with average of 27ºC. However, in the afternoon, the temperature of the pavement can reach around 50ºC. Based on Figure 3, the temperature of modified asphalt with maximum Sasobit® content is above 90ºC. Therefore, at 50ºC, the asphalt still does not soften. Thus, the Sasobit® modified asphalt helps to resist the deformation in pavement.

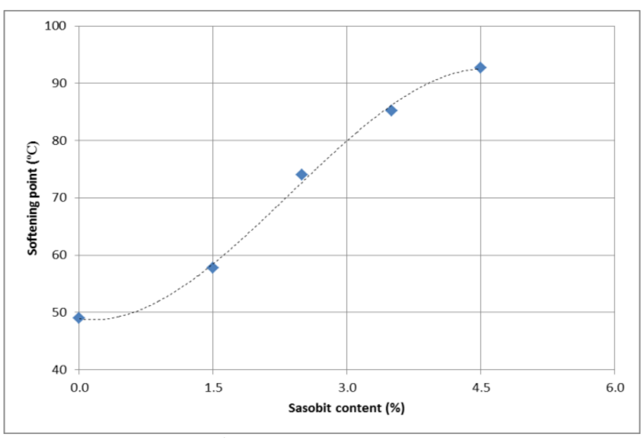


Figure 3 Softening pointversus Sasobit® content

3.3 Penetration Index

Based on Table 1, the penetration index significantly increases with increasing Sasobit® content. The decrease in penetration and increase in softening point indicate an increase in hardness of the modified bitumen. In addition the increase in PI value also reveals that Sasobit® reduces the temperature susceptibility of the bitumen.

Table 1 Penetration index of Sasobit® modified bitumen

Sasobit® content	Penetration (PEN)	Softening point (ºC)	Penetration index (PI)
0.0	61	49.0	-1.0
1.5	41	57.8	0.5
2.5	32	74.0	2.5
3.5	25	85.3	3.5
4.5	19	92.8	3.8

3.4 Stability

In order to ensure the data from penetration test was valid, stability test had been conducted and the results are presented in Figure 4. The results seem agreed with the penetration values, where the addition of Sasobit® increases the bitumen hardness. In other words, it supports that increasing the Sasobit® content caused the increase in the stability. The average stability of conventional asphalt mix is 15.2kN. However, with the addition of Sasobit®, the stability value can increase by as much as up to 1.4 times compared to mix without Sasobit®. Nevertheless, all mixes indicated stability values more than the required 8kN stipulated in the JKR specification [1].

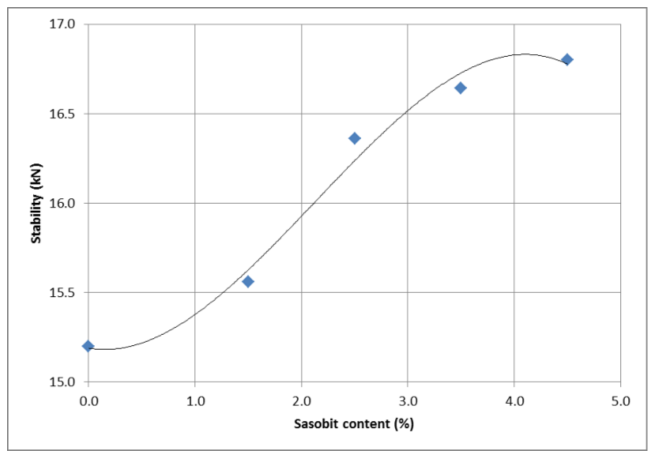


Figure 4 Relationship between stability and Sasobit® content

3.5 Flow

A representation of the relationships between Marshall Compaction flow rate and Sasobit® content is presented in Figure 5. The trends lines indicate that the flow values of Marshall Specimens compacted from asphalt mix exhibit an exponential curve with Sasobit® content. The results also show that the addition of Sasobit® at different percentage significantly assists in lowering the amount of flow. It can be said that the use of Sasobit® in asphalt mixes reduces flow of Marshall Specimens. Marshall Compaction flow of specimens reduces from 4.0mm to 3.2mm when the Sasobit® content increases from 0% to 4.5%. The lowest flow reduction was reached with 4.5 % amount of Sasobit® and was about 20 % lower compared to the flow of specimens of control mixture. It can be concluded that the use of Sasobit® in asphalt mixes reduces flow of Marshall Specimens.

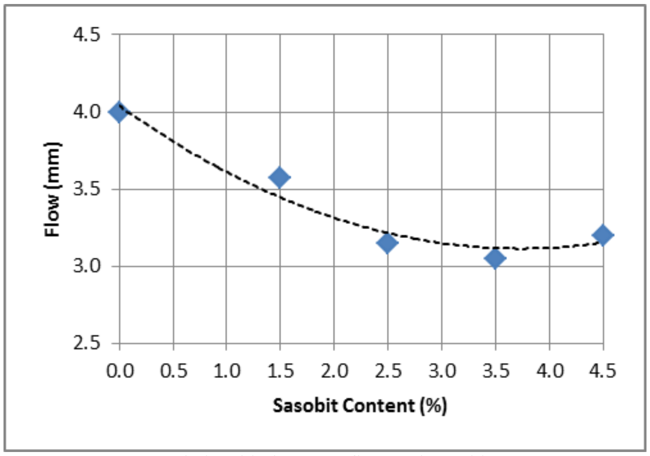


Figure 5 Relationship between flow and Sasobit® content

3.6 Stiffness

The stiffness test results of asphaltic concrete containing Sasobit® are graphically presented in Figure 6. The stiffness of the mix is related to the Sasobit® content through the polynomial curve illustrated in the plotting area. The curve indicate that specimens with 4.5% Sasobit® exhibit higher stiffness than 0%, 1.5%, 2.5%, and 3.5%, respectively. This indicates that the addition of Sasobit® has clear effects on stiffness values and can be attributed to sasobit structure within bitumen15-16 [19].

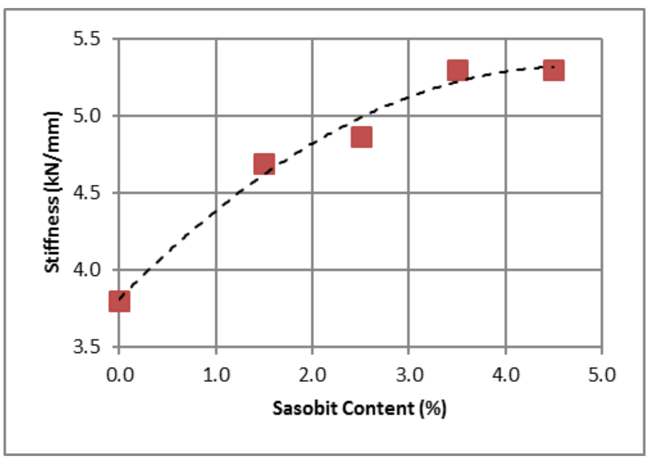


Figure 6 Relationship between stiffness and Sasobit® content

3.7 Abrasion Loss

In this study, three different rotations have been used to evaluate the loss in abrasion i.e. 100, 200 and 300 rotations. Figure 7 shows the abrasion loss of specimen versus Sasobit® content. It was found that the abrasion loss of specimens increase with the increasing of Sasobit® content. The highest percentage of abrasion loss occurs at 4.5% Sasobit®. It can be seen that mixture with the highest percentage of Sasobit® gives the lowest bonding strength. This is possibly due to the reduction in the ability of bitumen to coat the aggregate particles due to the increase in the viscosity of the bitumen when modified with Sasobit®. The amount of abrasion loss increase significantly with the increases of Sasobit® content except for 1.5%. This is possibly an indication that 1.5% Sasobit® content is the optimum rate to reduce the abrasion loss.

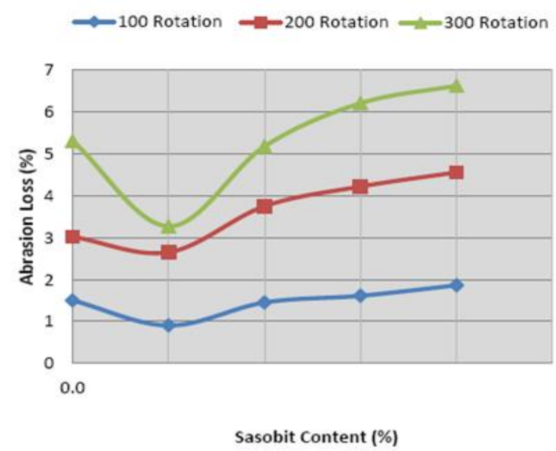


Figure 7 Relationship between abrasion loss and Sasobit® content

3.8 Resilient Modulus

The resilient modulus is simply the modulus of elasticity when the asphalt sample is loaded within its elastic range where the deformation is fully recoverable. In this study, the stiffness characteristic of asphalt materials was determined through resilient modulus test. From Figure 8, an increase in Sasobit® percentage results in an increase of resilient modulus. It was clearly showed that specimen with highest content of Sasobit® possessed a better stiffness modulus (2400MPa) compared to specimen with less Sasobit® (2285MPa). This indicates that specimen with higher content of Sasobit® will create a stiffer asphalt mixture as a result of the modified binder.

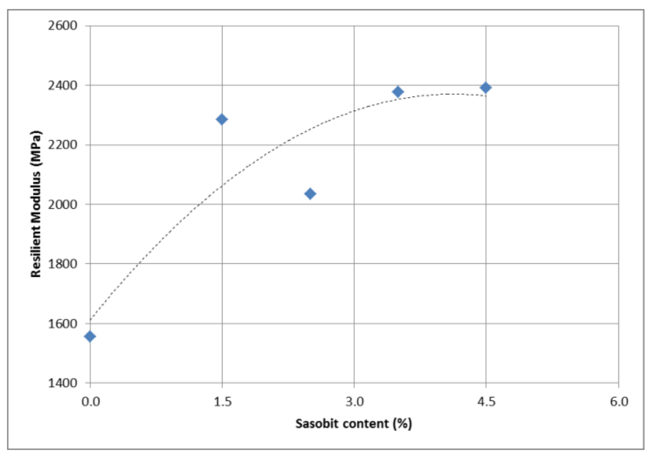


Figure 8 Relationship between modulus of resilient and Sasobit® content

4.0 CONCLUSION

This study provides a laboratory evaluation on the properties of bitumen (penetration grade 60/70) modified with Sasobit®. The investigation was then furthered on the properties of asphalt mixture containing the Sasobit® modified bitumen. Based on the findings, it was found that the addition of Sasobit® has hardened the bitumen and reduces its temperature susceptibility as measured by the penetration and softening point tests. This is also supported by the results obtained from the performance tests (stability and resilient modulus) where the addition of Sasobit® increases the asphalt mixture stability and modulus compared to the controlled specimen. However the increase in the bitumen stiffness has reduced its ability to coat the aggregate particles and the bonding strength as shown by the abrasion loss.

Acknowledgement

The support provided by Malaysian Ministry of Higher Education (MOHE) and Universiti Teknologi Malaysia (UTM) in the form of a research grant (Vote No. Q.J130000.2622.09J75) for this study is very much appreciated.

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